A Fuzzy Study on the Analysis of Cervical Cancer among women using Combined Disjoint Block Fuzzy Cognitive Maps (CDBFCMs)

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***Abstract*— In this paper we analyzed the impact of cervical cancer among women using Combined Disjoint Block Fuzzy Cognitive Maps (CDBFCM) model. The Combined Disjoint Block FCM is effective in grouping the concepts when they are in large numbers. This paper is organized five sections. First section gives the information about development of Fuzzy logic. Second Section gives theoretical foundations and unique features of fuzzy logic. In the third section the preliminaries of Fuzzy Cognitive maps and Combined Disjoint Block Fuzzy Cognitive Maps were discussed. We deal the problem of cervical cancer, in section four and we explain method of determining the hidden pattern. Final section gives the conclusion based on our study.**

***Index Terms*—Cervical Cancer, Combined Disjoint Block Fuzzy Cognitive Maps, Fuzzy Cognitive Maps, Risk Factors.**

I. Introduction

In 1965, L.A. Zadeh has introduced a mathematical model called Fuzzy Cognitive Maps. After a decade in the year 1976, Political scientist R. Axelord [10] used this fuzzy model to study decision making in social and political systems. Then B. Kosko [4]–[6] enhanced the power of cognitive maps considering fuzzy values for the concepts of the cognitive map and fuzzy degrees of interrelationships between concepts. FCMs can successfully represent knowledge and human experience, introduced concepts to represent the essential elements and the cause and effect relationships among the concepts to model the behavior of any system. It is a very convenient simple and powerful tool, which is used in numerous fields such as social economical and medical etc. in this paper In this paper we use the Neutrosophic Cognitive Maps (NCMs) created by Florentine Smarandache [11],[12],[14] which is an extension / combination of the Fuzzy Cognitive Maps (FCMs)in which indeterminacy is included. It has also become very essential that the notion of Neutrosophic logic plays a vital role in several of the real world problems like law, medicine, industry, finance, IT, stocks and share etc.

II. Theoretical Foundations

A. Fuzzy Logic

Fuzzy logic starts with and builds on a set of user supplied human language rules. The fuzzy system converts these rules into their mathematical equivalents. This simplifies the job of the system designer and the computer, and results in much more accurate representations of the system behavior in the real world. Fuzzy logic's approach to control problems mimics how a person would make decisions, only much faster [13].

B. Unique Features Of Fuzzy Logic

Fuzzy logic offers several unique features that make it a particularly good choice for many control problems.

1. It is inherently robust since it does not require precise, noise-free inputs and can be programmed to fail safely if a feedback sensor quits or is destroyed. The output control is a smooth control function despite a wide range of input variations.
2. Since the Fuzzy logic controller processes user-defined rules governing the target control system, it can be modified and tweaked easily to improve or drastically alter system performance. New sensors can be incorporated into the system simply by generating appropriate governing rules.
3. Fuzzy logic can control nonlinear systems that would be difficult or impossible to model mathematically. This opens doors for control systems that would normally be deemed unfeasible for automation.

III. Basic Notations And Definitions

A. Fuzzy Cognitive Maps

Fuzzy Cognitive Maps are fuzzy structures that strongly resemble neural networks, and they have powerful and far-reaching consequences as a mathematical tool for modeling complex systems. It was a fuzzy extension of the

cognitive map pioneered in 1976 by political scientist Robert Axelord, who used it to represent knowledge as an interconnected, directed, bi-level logic graph. Till today there are over a hundred research papers which deal with FCMs, and the tool has been used to study real world situations as varied as stock investment analysis to supervisory system control and child labor to community mobilization against the AIDS epidemic. It is a very convenient, simple and powerful tool which is used in numerous fields such as social, economical, medical and so on.

B. Basic Notations And Definitions

Fuzzy Cognitive Maps (FCMs) are more applicable when the data in the first place is an unsupervised one. The FCMs work on the opinion of experts. CDBFCMs was first introduced by W.B. Vasantha Kandasamy and A. Victor Devadoss in the year 2004 to study the effects of chemical pollution among the agriculture labourers in the Chengalpattu district, Tamil Nadu [13, 14]. It is a collection of classes and causal relations between classes. This method is very well suitable for our study.

C. Fuzzy Nodes

When the nodes of the FCM are fuzzy sets then they are called as fuzzy nodes.

D. Simple FCMs

FCMs with edge weights or causalities from the set $\{-1, 0, 1\}$ are called simple FCMs.

E. FCMs

A FCM is a directed graph with concepts like policies, events etc, as nodes and causalities as edges. It represents causal relationships between concepts.

F. Adjacency Matrix Of FCMs

Consider the nodes/concepts $C_1, C_2, \cdots, C_n$ of the FCM. Suppose the directed graph is drawn using edge weight $e_{ij} \in \{-1, 0, 1\}$. The matrix E is defined by $E = (e_{ij})$ where e_{ij} is the weight of the directed graph $C_i C_j$. E is called the adjacency matrix of FCM, also known as the connection matrix of the FCM. It is important to note that all matrices associated with an FCM are always square matrices with diagonal entries as zero.

G. Instantaneous State Vector

Let $C_1, C_2, \cdots, C_n$ be the nodes of an FCM. $A = (a_1, a_2, \cdots, a_n)$ where $e_{ij} \in \{-1, 0, 1\}$. A is called the instantaneous state vector and it denotes the on-off position of the node at an instant. $a_i = 0$ if a_i is off and $a_i = 1$ if a_i is on for $i = 1, 2, \ldots, n$.

H. Cyclic And Acyclic

Let $C_1, C_2, \cdots, C_n$ be the nodes of an FCM. Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \cdots, \overrightarrow{C_iC_j}$ be the edges of the FCM $(i \neq j)$. Then the edges form a directed cycle. An FCM is said to be cyclic if it possesses a directed cycle. An FCM is said to be acyclic if it does not possess any directed cycle.

I. Feedback

An FCM is said to be cyclic if it has a feedback.

J. Dynamical System

When there is a feedback in an FCM, i.e., when the causal relations flow through a cycle in a revolutionary way, the FCM is called a dynamical system.

K. Hidden Pattern

Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \cdots, \overrightarrow{C_iC_j}$ be a cycle. When C_i is switched on if the causality flows through the edges of the cycle and if it again causes C_i, we say that the dynamical system goes round and round. This is true for any node C_i for $i = 1, 2, \ldots, n$. The equilibrium state for this dynamical system is called the hidden pattern.

L. Fixed Point

If the equilibrium state of a dynamical system is a unique state vector, then it is called a fixed point. Consider a FCM with $C_1, C_2, \cdots, C_n$ as nodes. For example, let us start the dynamical system by switching on C_1. Let us assume that the FCM settles down with C_1 and C_n on i.e., in the state vectors remains as $(1, 0, 0, \ldots, 0)$ is called fixed point.

M. Limit Cycle

If the FCM settles down with a state vector repeating in the form $A_1 \to A_2 \to \cdots \to A_i \to A_1$ then this equilibrium is called a limit cycle.

N. Combined FCM

Finite number of FCMs can be combined together to produce the point effect of all the FCMs. Let $E_1, E_2, \cdots, E_p$ be the adjacency matrices of the FCMs with nodes $C_1, C_2, \cdots, C_n$ then the combined FCM is got by adding all the adjacency matrices $E_1, E_2, \cdots, E_p$. We denote the combined FCM adjacency matrix by $E = E_1 + E_2 + \cdots + E_p$.

O. Combined Disjoint Block FCM Of Unequal Classes

Let $C_1, C_2, \cdots, C_n$ be n distinct attributes of a problem n very large and a prime. If we divide n into k equal classes i.e., $k/n = t$ which are disjoint and if we find the directed graph of each of these k classes of attributes each, then their corresponding connection matrices are formed and these connection matrices are joined as blocks to form a $n \times n$ matrix. This $n \times n$ connection matrix forms the combined disjoint block FCM of equal classes. If the classes are not divided to have equal attributes but if they are disjoint classes we get a $n \times n$ connection matrix called the combined disjoint block FCM of unequal classes/size.

P. Threshold And Updated

Suppose $A = (a_1, a_2, \cdots, a_n)$ is a vector which is passed into a dynamical system E then $AE = (a_1', a_2', \cdots, a_n')$ after upholding and updating the vector. Suppose we get $(b_1, b_2, \cdots, b_n)$ we denote that by $(a_1', a_2', \cdots, a_n') \mapsto (b_1, b_2, \cdots, b_n)$. Thus the symbol '$\mapsto$' means the resultant vector has been threshold and updated.

Q. Advantages and Disadvantages of FCM

The advantages of this method are it is simple. When the data happens to be an unsupervised one the FCM comes handy. This is the only known fuzzy technique that gives the hidden pattern of the situation. As we have a very well-known theory, which states that the strength of the data depends on, the number or expert's opinions. At the same time the disadvantages of the combined FCM is when the weightings are 1 and -1 for the same C_i, C_j, we have the sum adding to zero thus at all times the connection matrices $E_1, E_2, \cdots, E_k$ may not be conformable for addition. Combined conflicting opinions tend to cancel out and assisted by the strong law of large numbers, the consensus emerges as the sample opinion approximates the underlying population opinion. This problem will be easily overcome if the FCM entries are only 0 and 1.

R. Method of Determining the Hidden Pattern

Let $C_1, C_2, \cdots, C_n$ be the nodes for the FCM, with feedback, let E be the associated adjacency matrix. Let us find the hidden pattern when C_1 is switched on. When an input is given as the vector $A_1 = (1,0,\cdots,0)$, the data should pass through the relation matrix E. This is done by multiplying A_i the matrix E. Let $A_iE = (a_1, a_2, \cdots, a_n)$ with the threshold operation that is by replacing a_i by 1 if $a_i > k$ and a_i by 0 if $a_i < k$ (k is a suitable positive integer). We update the resulting concept; the concept C_1 is included in the updated vector by making the first coordinate as 1 in the resulting vector. Suppose $A_iE \to A_2$ then consider A_2E and repeat the same procedure. This procedure is repeated till we get a limit cycle or a fixed point.

IV. Concepts of the Problem

A. Description of the problem

Cervical cancer, or cancer of the cervix, is cancer of the entrance to the uterus (womb). Unlike many other cancers, cervical cancer occurs early and strikes at the productive period of a woman's life. The incidence rises in 30–34 years of age and peaks at 55–65 years. Estimates suggest that more than 80% of the sexually active women acquire genital HPV by 50 years of age. According to World Health Organization, cervical cancer is the second biggest cause of female cancer mortality worldwide with 288,000 deaths yearly.

B. Combined Disjoint Block FCM

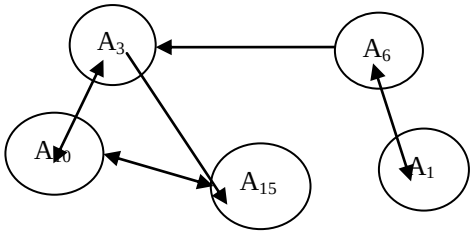
The problem is addressed via attributes using the notion of Combined Disjoint Block FCM (CDBFCM). Let $C_1, C_2, \cdots, C_n$ be 'n' nodes/attributes related with some problem. The n may be very large and a non-prime. Even though we have C-program to work finding the directed graph the related connection matrix maybe unwieldy. In such cases we use the notion of combined disjoint block fuzzy cognitive maps. We divide these n attributes into k equal classes and these k equal classes are viewed by k –experts and the corresponding directed graph and the connection matrices are got. Now these connection matrices are made into a $n \times n$ matrix and using C program the results are derived.

C. Attributes

A_1 - Pain During Sexual Intercourse
A_2 – Leakage of Urine
A_3 – Bleeding from Vagin
A_4 – Hydronephrosis
A_5 – Loss of Appetite
A_6 - Pelvic Pain
A_7 – Swollen Legs
A_8 – Constipation
A_9 – Smelly Vaginal Discharge
A_{10} – Vaginal Discharge (abnormal)
A_{11} – Longer Menstrual Cycle
A_{12} – Fatigue
A_{13} – Blood in Urine
A_{14}- Loss of Bladder Control
A_{15} – Blood in Vaginal Discharge

D. Application of Combined Disjoint Block FCMs to the study

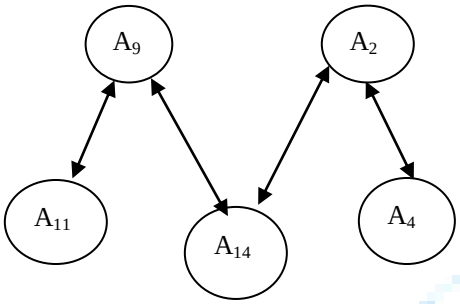
These 15 attributes are divided into 3 classes C_1, C_2 and C_3 with 5 in each class. Let $C_1 = \{A_3, A_6, A_{10}, A_{15}, A_1\}$, $C_2 = \{A_9, A_2, A_{11}, A_{14}, A_4\}$ and $C_3 = \{A_7, A_{12}, A_5, A_8, A_{13}\}$. Now we take the expert opinion for each of these classes and take the matrix associated with the combined disjoint block FCMs. The experts opinion for the class $C_1 = \{A_7, A_{12}, A_5, A_8, A_{13}\}$ in the form



The attributes are bleeding from vagina, Pelvic pain, vaginal discharge, Blood in vaginal discharge, Pain during sexual intercourse. The related connection matrix is given by,

	A_3	A_6	A_{10}	A_{15}	A_1
A_3	0	0	1	1	0
A_6	1	0	0	0	1
A_{10}	1	0	0	1	1
A_{15}	1	0	1	0	0
A_1	0	1	0	0	0

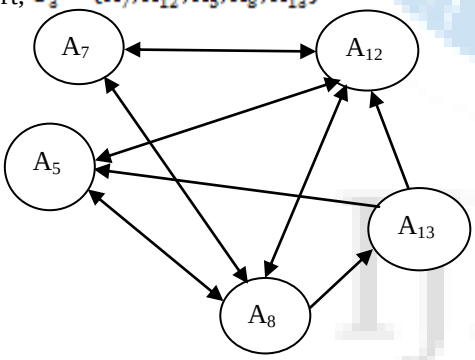
The directed graph is given by the expert on $\{A_9, A_2, A_{11}, A_{14}, A_4\}$ which forms the class C_2.



According to this expert the attributes are Smelly vaginal discharge, Leakage of urine, longer menstrual cycle, Loss of bladder control, Hydronephrosis. The related connection matrix is given by,

	A_9	A_2	A_{11}	A_{14}	A_4
A_9	0	0	1	1	0
A_2	0	0	0	1	1
A_{11}	1	0	0	0	0
A_{14}	1	1	0	0	1
A_4	0	1	0	1	0

Now we give the directed graph for class C_3 as given by the expert, $C_3 = \{A_7, A_{12}, A_5, A_8, A_{13}\}$



According to this expert the attributes are Swollen Legs, Fatigue, Loss of appetite, Constipation, Blood in urine. The related connection matrix is given by,

	A_7	A_{12}	A_5	A_8	A_{13}
A_7	0	1	0	1	0
A_{12}	1	0	1	1	0
A_5	1	1	0	1	0
A_8	1	1	1	0	1
A_{13}	0	1	1	0	0

Now Combined Disjoint Block Connection Matrix of the fuzzy cognitive maps B is given in the following matrix:

	A_3	A_6	A_{10}	A_{15}	A_1	A_9	A_2	A_{11}	A_{14}	A_4	A_7	A_{12}	A_5	A_8	A_{13}
A_3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
A_6	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
A_{10}	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
A_{15}	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
A_1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
A_9	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
A_2	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
A_{11}	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
A_{14}	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0
A_4	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
A_7	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
A_{12}	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0
A_5	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0
A_8	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1
A_{13}	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0

Suppose we consider the ON state of the attribute Hydronephrosis and all the other states are OFF the effect of $X = (000100000000000)$ on CDBFCM is given by

$XB = (101000000000000) = X_1$

$X_1B = (101100000000000) = X_2$

$X_2B = (101100000000000) = X_3 = X_2$

X_2 is the fixed point of the dynamical system. Thus when one experiences hydronephrosis, pain during sexual intercourse and bleeding from vagina are possible.

Suppose we consider the ON state of attributes pain during sexual Intercourse, pelvic Pain, Vaginal Discharge (abnormal), Loss of Bladder Control and all the other states are OFF. Now we study the effect on the dynamical system B. Let $G = (100001000100010)$ state vector depicting pain during sexual Intercourse, pelvic Pain, Vaginal Discharge (abnormal) and Loss of Bladder Control, passing the state vector G into the dynamical system B.

$GB = (0011001110111101) = G_1$ (say)

$G_1B = (1011011011111110) = G_2$ (say)

$G_2B = (1011011111111111) = G_3$ (say)

$G_3B = (1011011111111111) = G_4 = G_3$.

G_3 is the fixed point of the dynamical system. Thus when one experiences pain during sexual Intercourse, pelvic Pain, Vaginal Discharge (abnormal) and Loss of Bladder Control she may also experience bleeding from vagina, hydronephrosis, swollen legs, constipation, smelly vaginal discharge, vaginal discharge(abnormal), longer menstrual cycle, fatigue, blood in urine, blood in vaginal discharge.

Suppose we consider the ON state of attributes constipation, longer menstrual cycle, loss of bladder control, blood in vaginal discharge and all the other states are OFF. Now we study the effect on the dynamical system B. Let $H = (000000010010011)$ state vector depicting constipation, longer menstrual cycle, loss of bladder control, blood in vaginal discharge passing the state vector H into the dynamical system B.

$HB = (000001000011111) = H_1$

$H_1B = (000000111011111) = H_2$

$H_2B = (000001101111111) = H_3$

$H_3B = (000001111111111) = H_4$

$H_4B = (000001111111111) = H_5 = H_4$.

H_4 is the fixed point of the dynamical system. Thus when one experiences constipation, longer menstrual cycle, loss of bladder control and blood in vaginal discharge, she may also experience pelvic pain, swollen legs, smelly vaginal discharge, vaginal discharge(abnormal), fatigue, blood in urine.

Suppose we consider the ON state of attributes bleeding from vagina, smelly vaginal discharge and all the other states are OFF. Now we study the effect on the dynamical system B. Let $P = (001000001000000)$ state vector depicting attributes bleeding from vagina and smelly vaginal discharge passing the state vector H into the dynamical system B.

$PB = (100101100100000) = P_1$

$P_1B = (101100111100000) = P_2$

$P_2B = (101101101100000) = P_3$

$P_3B = (101101111100000) = P_4$

$P_4B = (101101111100000) = P_5 = P_4$.

P_4 is the fixed point of the dynamical system. Thus when one experiences bleeding from vagina and smelly vaginal discharge, she may also experience pain during sexual intercourse, hydronephrosis, pelvic pain, swollen legs, constipation, vaginal discharge(abnormal).

V. Conclusion and Suggestions

A. Conclusion

We analyzed the symptoms of cervical cancer using CDBFCM model. The limit point of the dynamical system reveals that the attributes A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8, A_9, A_{10}, A_{11}, A_{12}, A_{13}, A_{14}, A_{15} are the major causes of cervical cancer. They are pain during sexual intercourse, leakage of urine, bleeding from vagina, Hydronephrosis, loss of appetite, pelvic pain, swollen legs, constipation, smelly vaginal discharge, vaginal discharge (abnormal), longer menstrual cycle, fatigue, blood in urine, loss of bladder control, blood in vaginal discharge. When loss of bladder control is ON for state vectors G and H, then swollen legs, smelly vaginal discharge, vaginal discharge (abnormal), fatigue, blood in urine are found be the common output of both state vectors. This shows the relation between the state vectors.

B. Suggestion

We suggest that a person should undergo regular checks for early detection of cancerous tumor and that any abnormalities in the body should be taken note of and must be given careful attention.

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